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American plaice
Hippoglossoides platessoides

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American plaice is a sedentary, slow-growing flatfish ranging from southern Labrador to Rhode Island (Bigelow and Schroeder 1953). In the Gulf of Maine and Georges Bank area, individuals attain a maximum length of about 70 cm (28 inches) and ages in excess of 20+ years, with females growing faster than males after age 4 (Sullivan 1982, Dery unpubl.). Most American plaice in these waters are sexually mature by age 3 (Sullivan 1982).

American plaice tend to be distributed in deep water from 90 to 180 m, and do not occur in waters less than 25-35 m. Feeding and spawning migrations appear to be limited (Bigelow and Schroeder 1953, Pitt 1967, Sullivan 1982). Spawning in the Gulf of Maine extends from March through May, with peak activity in April and May (Bigelow and Schroeder 1953, Colton et al. 1979). Coastal waters along the Gulf of Maine are nurserygrounds for this species (Bigelow and Schroeder 1953).

Studies by Powles (1965, 1966) and Pitt (1967) validated hyaline zones on otoliths as annuli for American plaice in Canadian waters. Ageing techniques for the Gulf of Maine-Georges Bank region have not been validated (Lux 1969, 1970, Sullivan 1982). Although the hyaline zones are considered to be valid annuli, a large number of Gulf of Maine and Georges Bank American plaice otoliths are often difficult to interpret, exhibiting weak, diffuse, or split hyaline zones, and, occasionally, strong checks. Little documentation of such problems is available, although Powles (1966) noted the presence of checks on the otoliths of small fish.

Powles (1965) and Lux (1970) examined whole otoliths stored in glycerin; Pitt (1967) broke otoliths in half and examined the broken surfaces. Sullivan (1982) examined thin-sections of otoliths of specimens greater than 35 cm. Smaller otoliths were examined whole in glycerin.

Age determinations have been performed at the Woods Hole Laboratory by examination of the thin-section and cut surfaces of one otolith. Tranverse sections 0.20 mm thick are made precisely at the nucleus of the otolith. The other whole otolith may be used to verify the age from the section and for young fish with clear zone formation. Prior to examination, otoliths are stored dry. For purposes of consistency with terminology applied to otolith sections of other species described in the manual, the terms "dorsal," "ventral," "proximal," and "distal" are used to describe locations on sections as if the fish's left eye had not migrated, resulting in a change of orientation of the otoliths to a vertical position, one above the other. Generally, the right or dorsal otolith provides the best section for age interpretation. This otolith is relatively thick and has a deeper sulcus acusticus. This is important in locating annular zones on thin-sections.

Although glycerin is an effective "clearing" medium for enhancement of hyaline zones, it has not been used at this laboratory because of difficulties with edge interpretation of overly cleared otoliths. Whole otoliths or sections are viewed in ethyl alcohol against a dark background under reflected light. Magnifications of up to 50-60× are used in order to distinguish the closely spaced annuli near the edge of older plaice otoliths.

The size of the first annulus is somewhat variable according to time of hatching and individual growth differences. Annulus formation generally occurs during the winter months and seems to be influenced by temperature (Pitt 1967). American plaice sampled further inshore tend to form opaque edge earlier in the season than deeper-water fish, possibly in response to advanced warming of coastal waters. Younger fish also resume growth earlier than older individuals, with some otoliths exhibiting large amounts of opaque edge as early as April (Fig. 1). By October, most otoliths of young

fish have begun to form hyaline edge (Fig. 2), while otoliths of older fish may continue to exhibit opaque edge (Fig. 3). It is important to note that the transverse section will reveal less newly-formed edge than the otolith as a whole. More detailed information on time of annulus formation in the Georges Bank-Gulf of Maine area is not currently available since specimens were available only from spring and autumn survey sampling. By convention, a birthdate of 1 January is used. As of this date, an annulus is interpreted on the edge of the otolith until spring growth resumption.

The dark central kernel or nucleus of the otolith represents the larval-to-juvenile pelagic phase of growth described by Powles (1966) (Fig. 4). Surrounding this central kernel is a thin, weak hyaline ring or "settling check" (Fig. 4) possibly representing the change from pelagic to demersal habitat, and similar to the "pelagic" ring described by Nichy (1969) for the silver hake. This zone is sometimes evident through the surface of the whole otolith and may be confused with the first annulus, which is formed rather close to the nucleus (Powles 1966).

The first annulus is usually a relatively strong hyaline zone and is clearly marked in the sulcus area (Figs. 2 and 5). A few plaice otoliths exhibit an unusually large first annulus, with the settling check surrounding the nucleus (Fig. 1). The first annulus may also be very tiny and close to the nucleus, appearing as thin concentric rings of hyaline material (Fig. 6).

Several factors that appear to influence the clarity of annulus formation on plaice otoliths include depth, temperature, growth rate, and sampling location. Otoliths of plaice from deeper Gulf of Maine waters often have less distinct annuli, probably because seasonal influences on the growth of these fish are muted. Otoliths of faster-growing fish from the western part of the Gulf of Maine and Georges Bank also exhibit less distinct zones than those of the eastern Gulf of Maine and Scotian Shelf areas. These differences in growth rate are apparent from examination of age/length keys (Dery unpubl. data). Since stock structure in the Gulf of Maine is currently unresolved (F.E. Serchuk, Woods Hole Lab., pers. commun.), the significance of these regional differences is unclear.

Figures 1-8 show otolith sections with distinct annulus formation. Although annuli may be clearly evident on all parts of a section (Fig. 2), they are usually most distinct on the proximal side of a section from the right otolith in the area between the sulcus and the dorsal edge (Fig. 7). Annuli tend to be more compacted on the shorter ventral axis which could lead to erroneously low age estimates. Because of the depth of the sulcus on sections shown in Figures 3 and 7, the annuli are especially distinct. Figure 8 provides an example of very slow growth, with the third through eighth annuli formed very close together on the otolith of a fish of only 28 cm. These zones are quite distinct, however, on the proximal (sulcus) side of the section. After age 3, this otolith increased more in thickness than in width or length, resulting in the apparent layering of annuli.

Otoliths with split or diffuse annular zones are more difficult to read, but are nevertheless interpretable in the sulcus area where the hyaline zones are more clearly resolved. Figure 9 provides an example of a split, diffuse second annulus. This section could easily be overaged if interpreted along the transverse axis. However, only one distinct zone (second annulus), in addition to the first annulus and edge annulus, is evident in the sulcus area. Similarly, if numerous checks are formed in-between annuli (Fig. 10), age can be reliably interpreted only in the sulcus, because checks are not normally evident on this part of the section. Figure 11 shows a similar growth pattern for an older fish.

The sulcus area, however, is not always the most reliable part of the otolith section for age interpretation. Although the annuli of Figure 12 are most distinct in the sulcus area, the eleven annuli on the otolith section of Figure 13 are clearest along the dorsoproximal axis. On this section, two groups or clusters of annuli are evident: annuli 2, 3, 4, and 5, 6, 7. In Figure 14, annuli are much more distinct on the dorsal axis than in the sulcus, which is very difficult to interpret. Therefore, each section should be individually evaluated for the best location to interpret the annuli, and alternate locations should be used to verify age.

Individual otoliths of American plaice may exhibit both strongly and weakly defined hyaline zones, unlike individuals of other species which tend to show a consistent pattern of hyaline zone formation from year to year. The first several annuli may be distinct, with those of the outer zones poorly formed (Fig. 15), or the outer annuli may be more distinct and the central or mid zone of the otolith difficult to interpret (Fig. 16). This intra-otolith variability in definition of hyaline zones is typical of many American plaice otoliths.

On some otoliths, the growth patterns are so weak and variable that error in age interpretation is likely. On these otoliths, each hyaline zone must be carefully traced around the periphery of the section to determine whether or not it is continuous and therefore an annulus. The annular zones may appear as indistinct clusters of very thin hyaline rings. In Figure 17, the separation between the annuli is most evident on the distal side (bottom) of the section. A growth pattern such as this may be very difficult to interpret on a section from the thinner, more convex left otolith with a shallow sulcus (zones near the sulcus may be poorly defined). Figure 18 is a left otolith section with a shallow sulcus, which is, however, possible to interpret. The annuli along the dorsoventral axis are quite weak and diffuse, which is characteristic of some fast-growing plaice (Figs. 17 and 18). Some otoliths exhibit such poorly defined growth zones that they cannot be reliably interpreted (Fig. 19).

The otoliths of older American plaice can be quite difficult to age without a clear sulcus area on the section, or without an interpretable whole otolith. Figure 20 shows an otolith section from a 60-cm, age-17(18) fish where the growth pattern is increasingly complex toward the dorsal tip of the section. Annuli can be traced from the sulcus area, which is fairly easy to interpret, around the dorsal edge of the section. Age can also be determined using the whole otolith (Fig. 21), which shows 17 continuous hyaline zones.

In summary, American plaice otoliths often exhibit complex zone formation requiring cross-verification of age using both the thin section and/or whole otolith or sectioned otolith half. Young American plaice can be aged by simply examining the whole otolith in alcohol if the hyaline zones are strong and well defined. However, where the interpretation is not clear, preparation of a thin-sectioned otolith, preferably the left otolith, is necessary.

Citations

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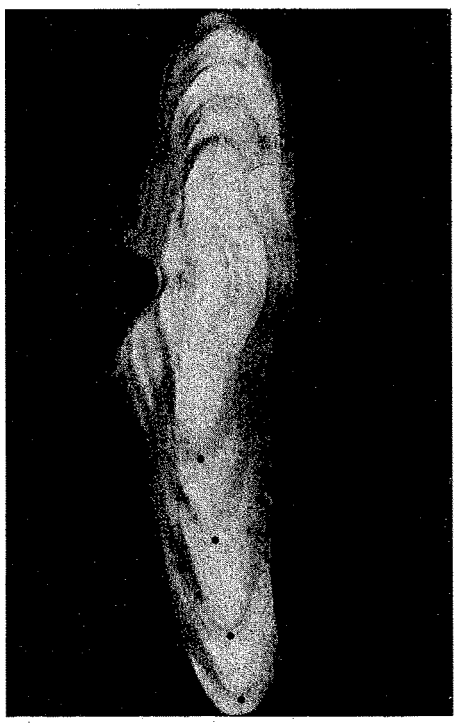

Figure 1

Otolith section of a 34-cm age 4+ American plaice collected in April showing a large first annulus and opaque edge.

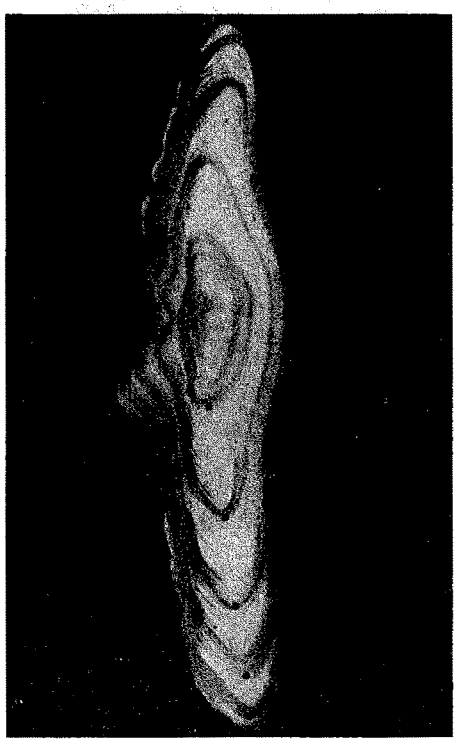

Figure 2

Otolith section of a 35-cm age 5+ American plaice collected in November showing strong clear annuli and a hyaline edge.

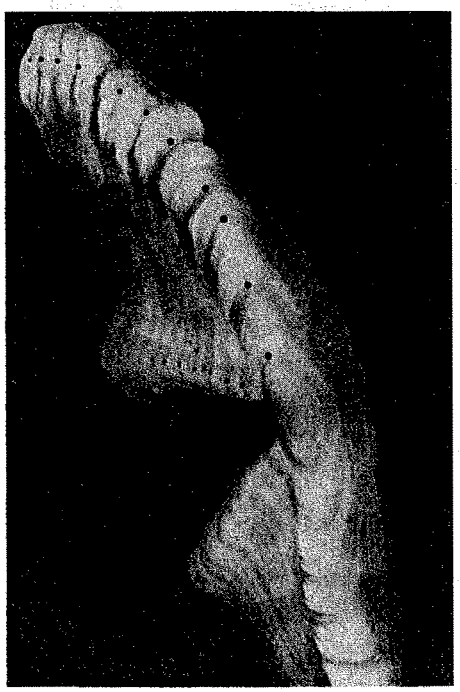

Figure 3

Ventral part of an otolith section from a 54-cm age 12+ American plaice collected in October showing a deep sulcus facilitating interpretation of annuli around that area.

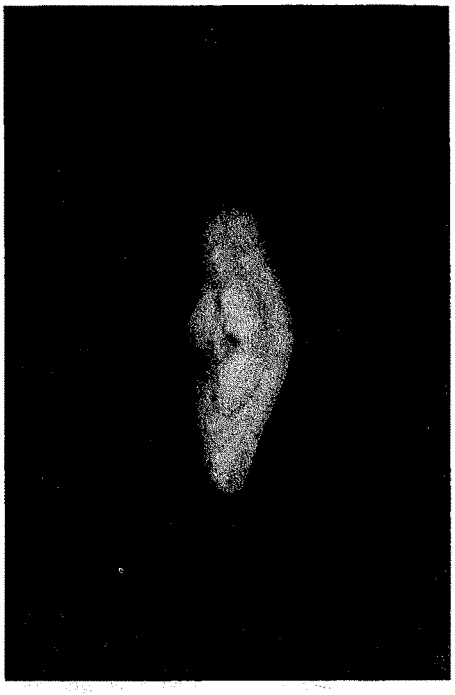

Figure 4
Otolith section of a 9-cm age 0+ American plaice collected in November showing a well defined larval zone and settling check.

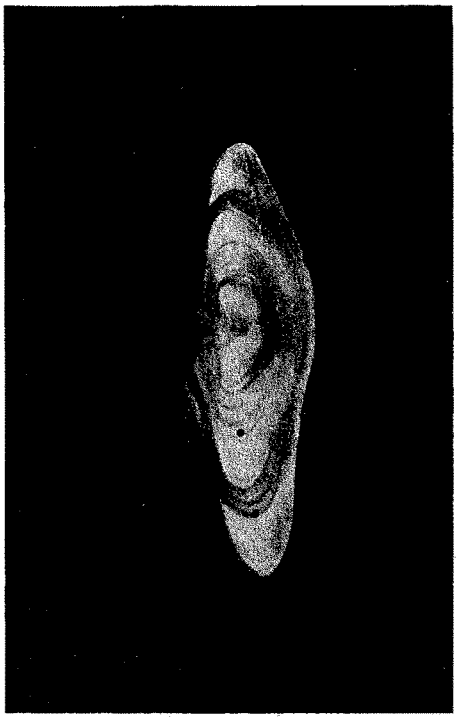

Figure 6
Otolith section of a 16-cm age 2+ American plaice collected in October showing a strong, tiny first annulus.

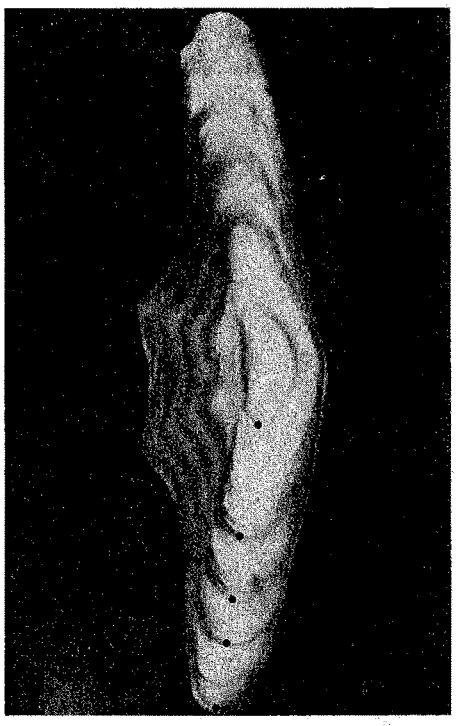

Figure 5
Otolith section of a 33-cm age-5 American plaice collected in March showing strong clear annuli, especially around the sulcus, and split fifth annulus.

Figure 7
Otolith section of a 48-cm age-10 female American plaice collected in May showing a deep sulcus and strong clear annuli.

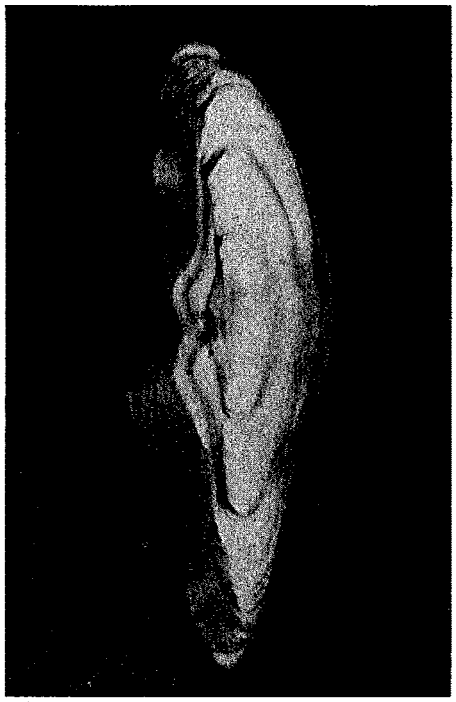

Figure 8
Otolith section of a 28-cm age-8 male American plaice collected in April showing very slow growth, with closely spaced annuli layered on the proximal part of the section.

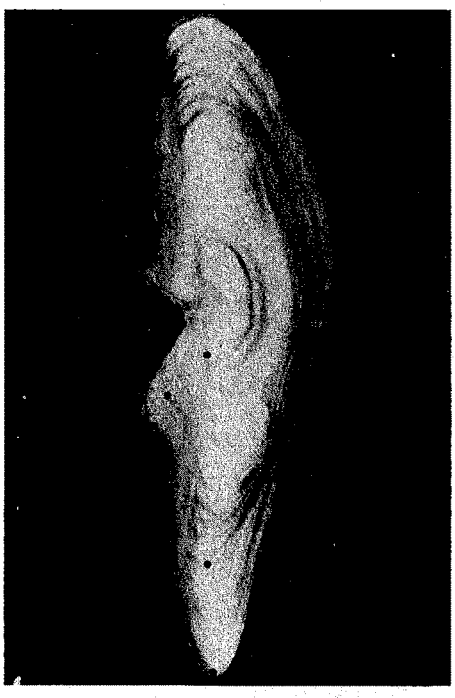

Figure 9
Otolith section of a 25-cm age-3 American plaice collected in April showing a split diffuse second annulus, interpretable near the sulcus.

Figure 10
Otolith section of a 23-cm age 4+ American plaice collected in April showing split zones and checks.

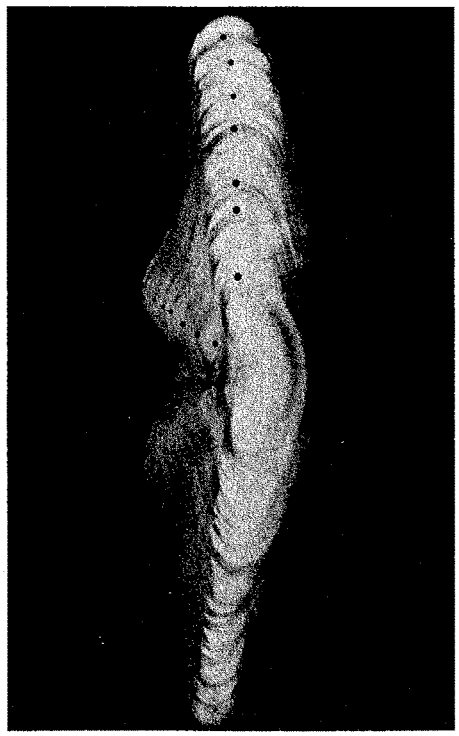

Figure 11
Otolith section of a 34-cm age 7+? American plaice collected in April showing split zones and checks.

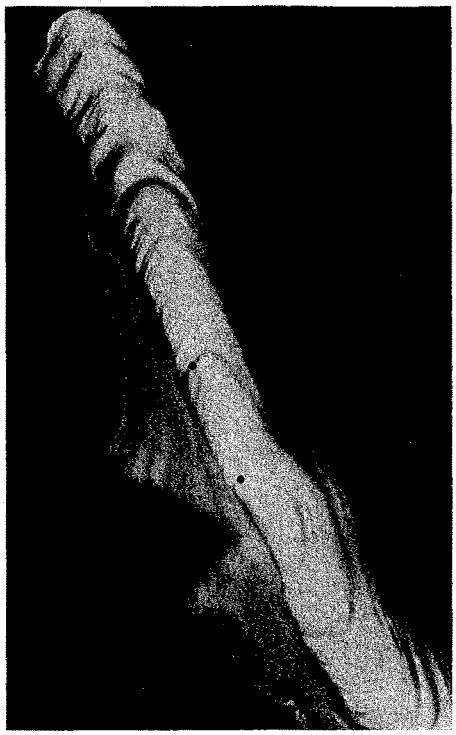

Figure 12
Otolith section of a 55-cm age-9 American plaice collected in April showing annuli clearly defined near the sulcus, but becoming more diffuse out to the dorsal edge.

Figure 13
Otolith section of a 63-cm age-11? American plaice showing groups of clustered annuli 2-3-4, 5-6-7, and 8-9-10-11.

Figure 14
Otolith section of a 63-cm age-13 American plaice collected in May showing annuli more distinct along the dorsal axis than near the sulcus.

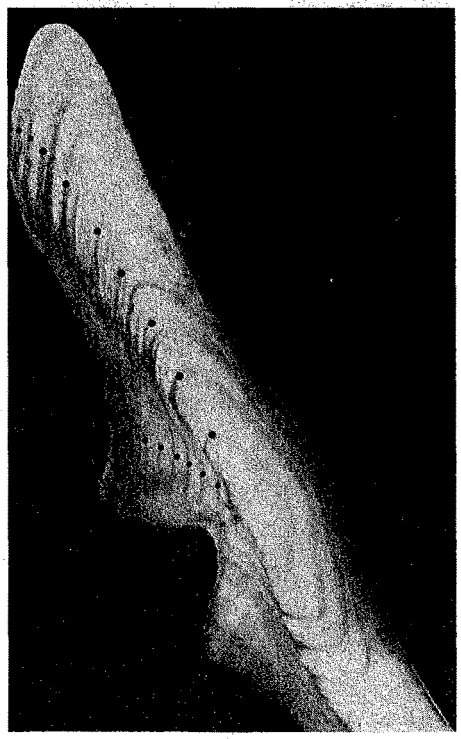

Figure 15
Otolith section of a 56-cm age 9+ or 10+ American plaice collected in October showing weak annuli formed after the fourth annulus.

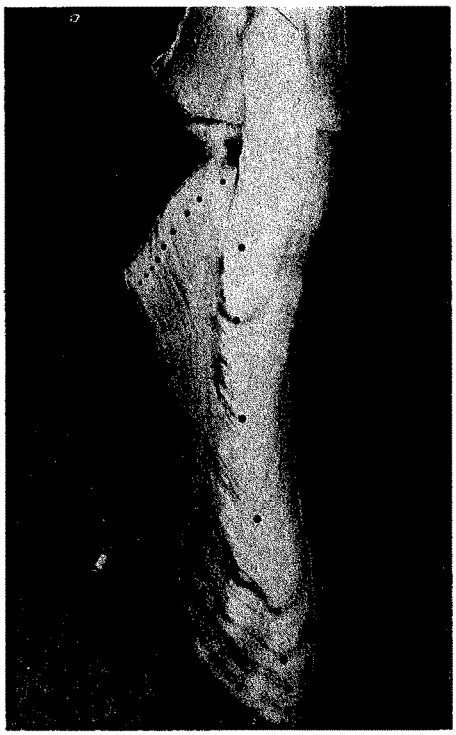

Figure 16
Otolith section of a 56-cm age-10 American plaice collected in April showing weak, diffuse third, fourth, and fifth annuli.

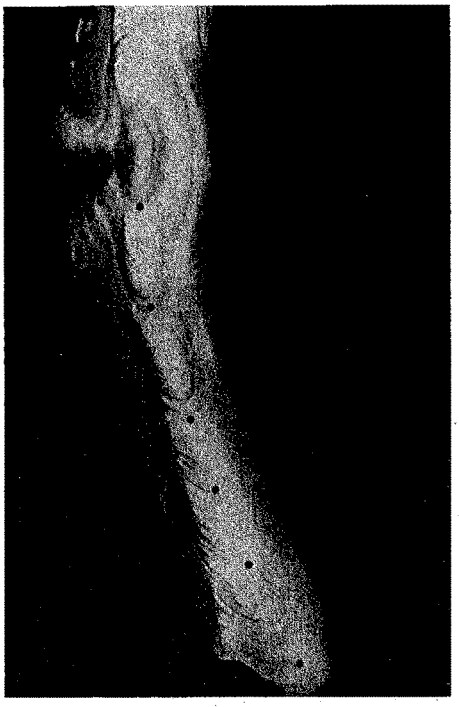

Figure 18
Left otolith section of a 57-cm age-7 American plaice collected in April showing weak, diffuse annuli 4-7.

Figure 17
Otolith section of a 53-cm age 6+? American plaice collected in October showing very indistinct, diffuse annuli, somewhat distinguishable on the distal (bottom) side of the section.

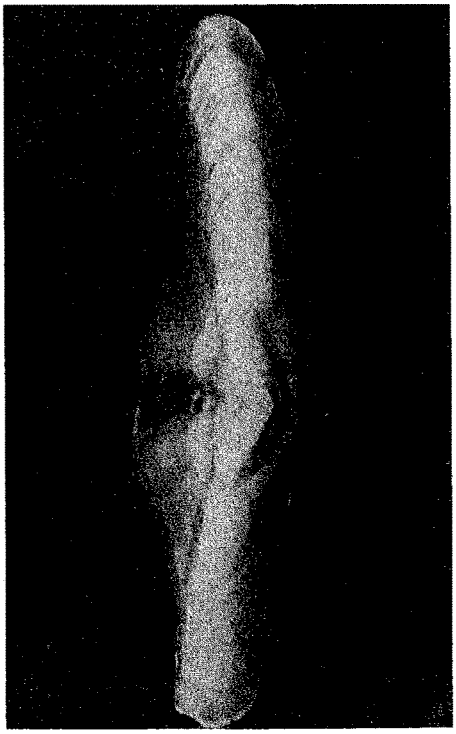

Figure 19
Otolith section of a 33-cm age ? American plaice collected in April showing very weak diffuse annuli.

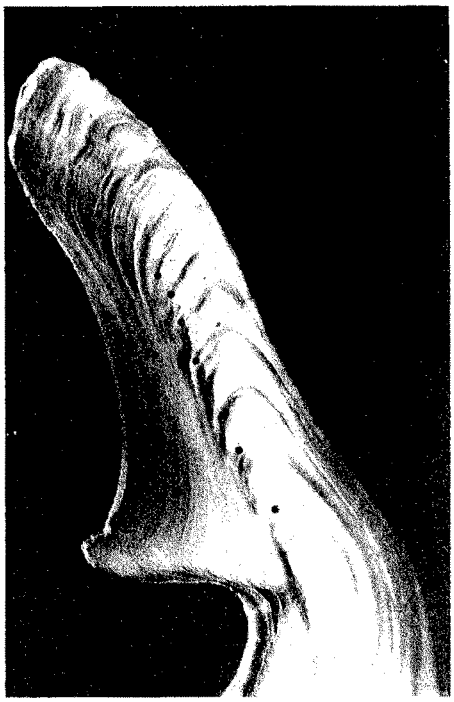

Figure 20
Dorsal part of an otolith section from a 60-cm age-17(18) American plaice collected in April showing increasingly diffuse annuli out to the dorsal edge.

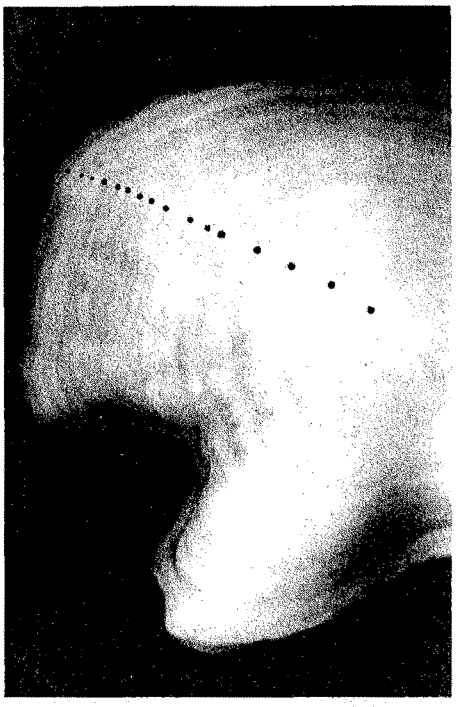

Figure 21
Whole otolith from the American plaice of Figure 20 showing 17 or 18 continuous hyaline zones.